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Space & Technology Division

Microwave Photonic Signal Processing for Wide Bandwidth Systems

DARPA Analog Optical Signal Processing Study Group

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Advances in Solid State Electronics Enabling Systems at Higher Frequency

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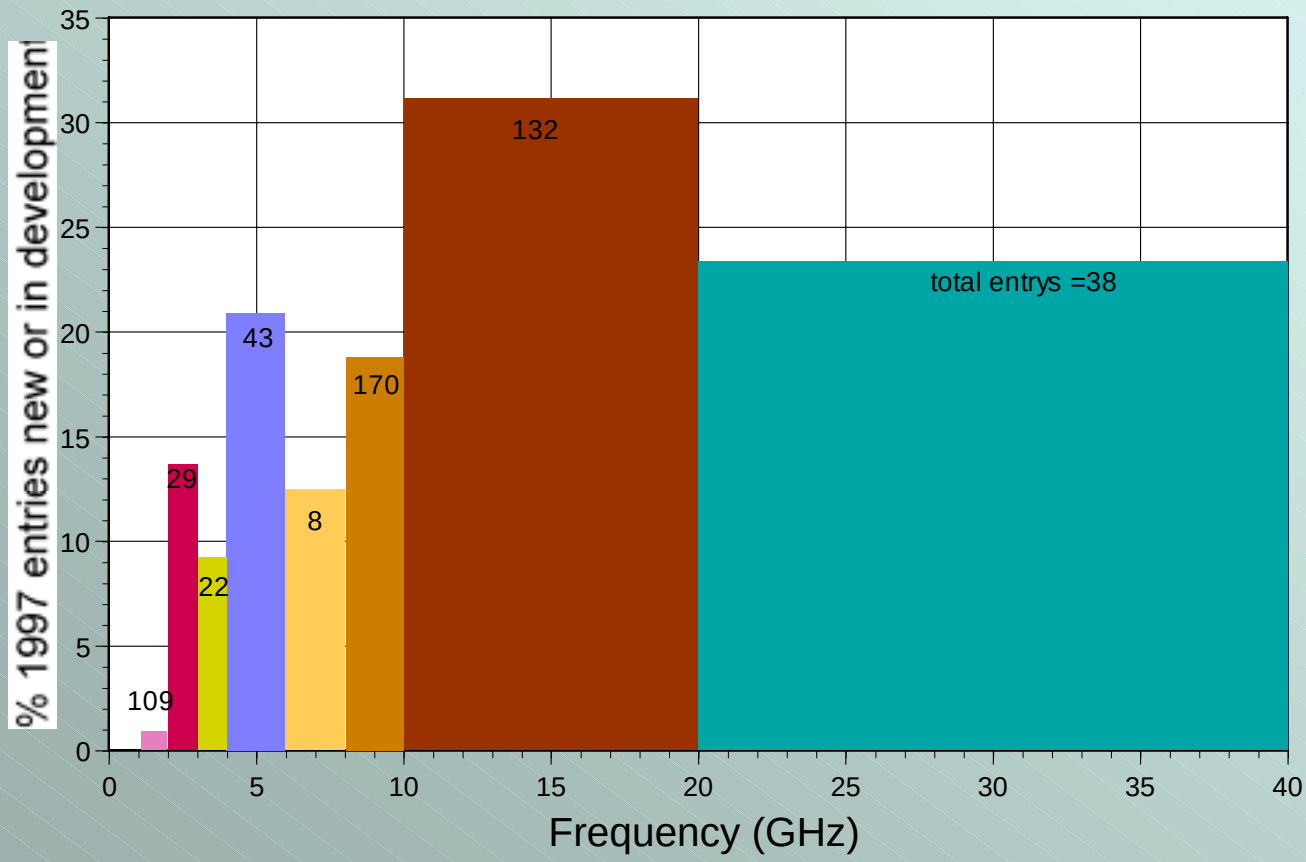
New Activity Reported in Janes 1997 Radars and ELINT Systems



So Much Bandwidth, So Little Time

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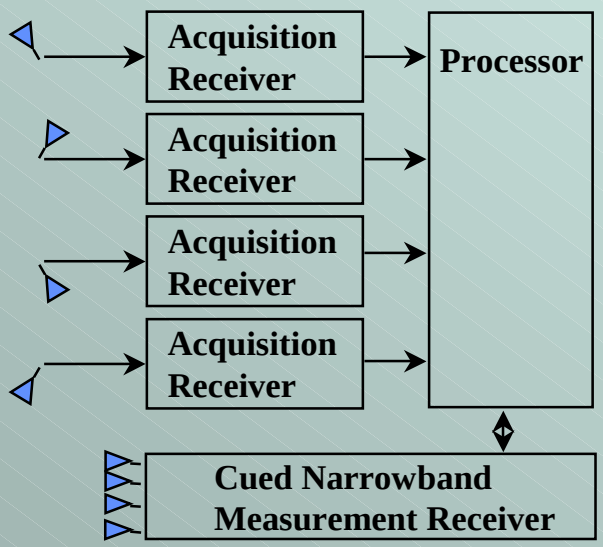

- Typical High Performance ESM Architecture
- Channelized Acquisition Receiver
  - 500 MHz to 1 GHz Bandwidth
  - 50 MHz Channels
- Cued Measurement Receiver
  - 4 to 5 Interferometer Channels
  - 50 MHz Bandwidth
- Desired Detection / Measurement Time < 2 sec.

Dwell Time ~ 50 msec. / subband / sector:

- Time To Search 2 to 18 GHz With 500 MHz Rx. = 50 x 4 x 32 = 6.4 sec
- Time To Search 2 to 40 GHz With 500 MHz Rx. = 50 x 4 x 76 = 15.2 sec
- Time To Search 2 to 90 GHz With 500 MHz Rx. = 50 x 4 x 176 = 35.2 sec

Need : Increased Acquisition Receiver Bandwidth

Photonics Offers Viable Wideband Processing Capability

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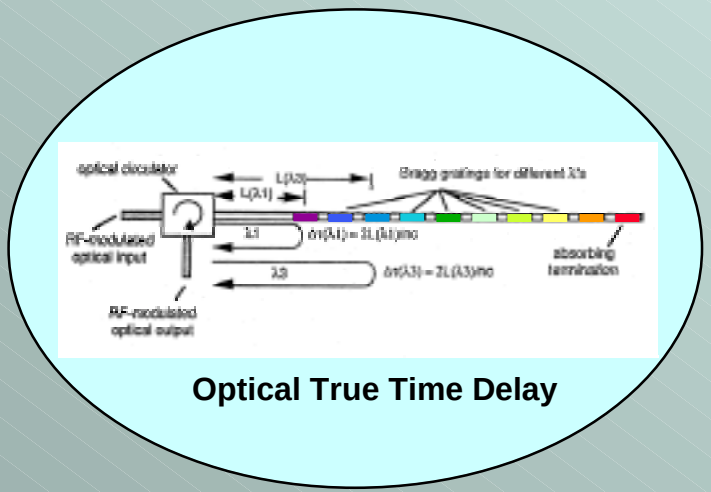
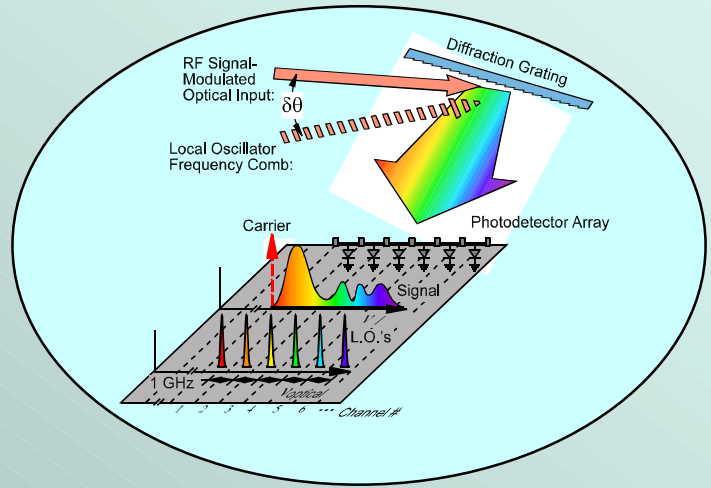
Time-Domain Processing



Optical True Time Delay

- Large (10^3) time-bandwidth products.

Frequency-Domain Processing



- 10 -100 GHz front-end channelizer bandwidths demonstrated.

Wide Band, High Fidelity Signal Routing

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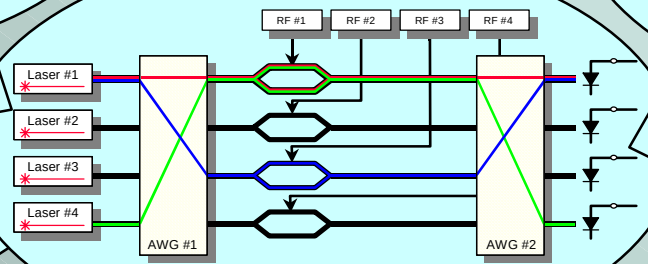
Mission Need

- Antenna farm switching
- RF signal 1-to-N broadcast

Key Enabling Technology

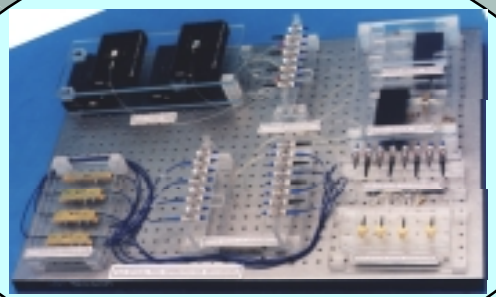
Arrayed Waveguide Grating

Photonic Functional Block Diagram

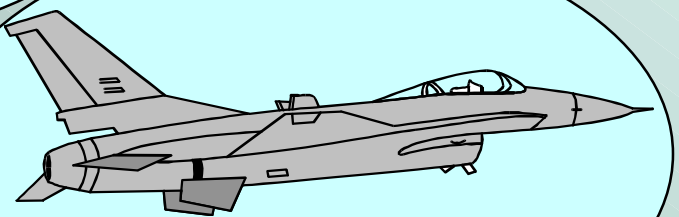


Splitterless Optical Broadcast Switch (SOBS)

Proof-of-Concept Demonstration



Avionic Integrated RF Sensor Suite



Optical Channelizer as Signal Preprocessor for Wideband Warning Receiver

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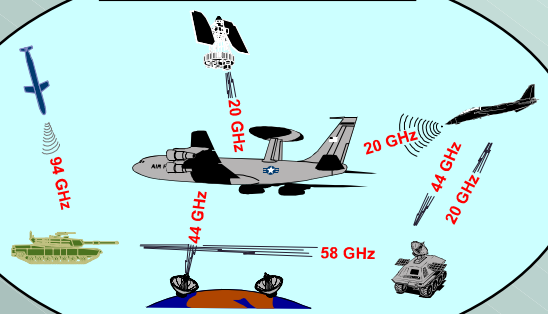
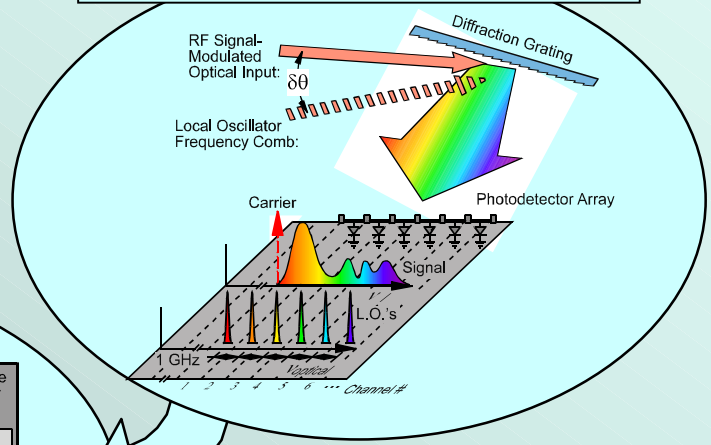
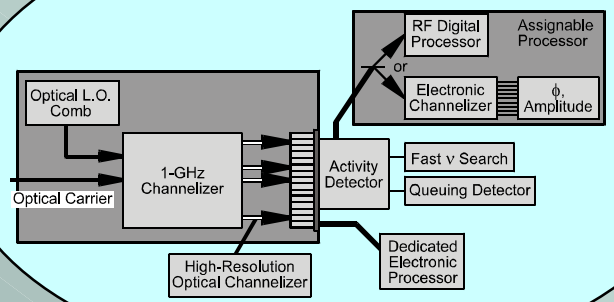
Mission Need



Key Enabling Technology

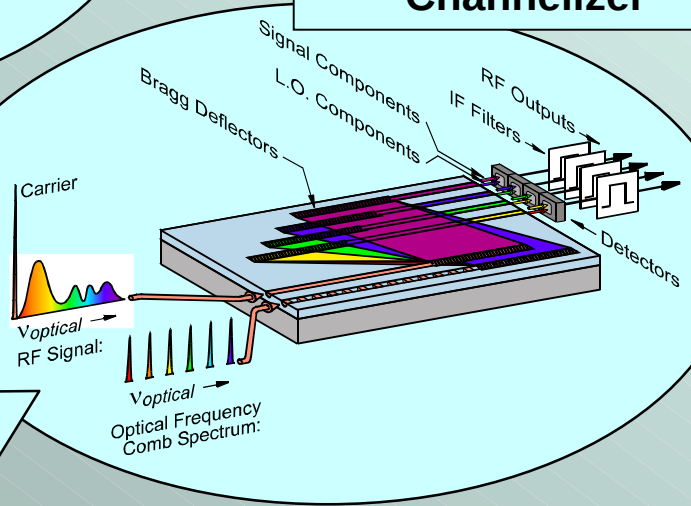


Photonic Subsystem Block Diagram



TRW / DARPA 100 GHz Proof-of-Concept Demonstration

RFLICS Modular Advanced Signal Channelizer



Optical Channelizer Performance

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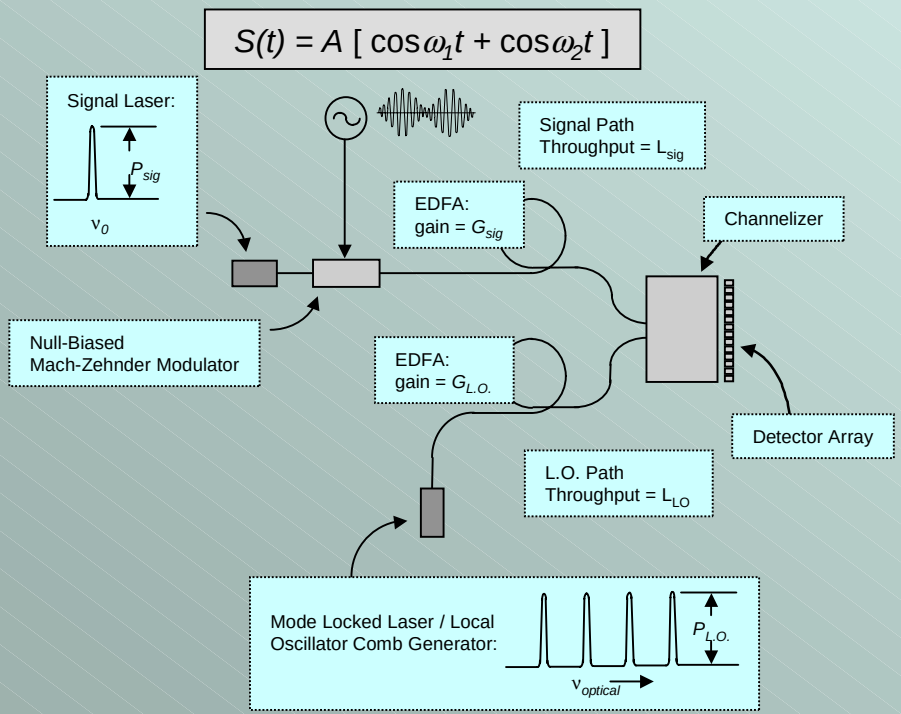
Two-Tone Spur-Free Dynamic Range

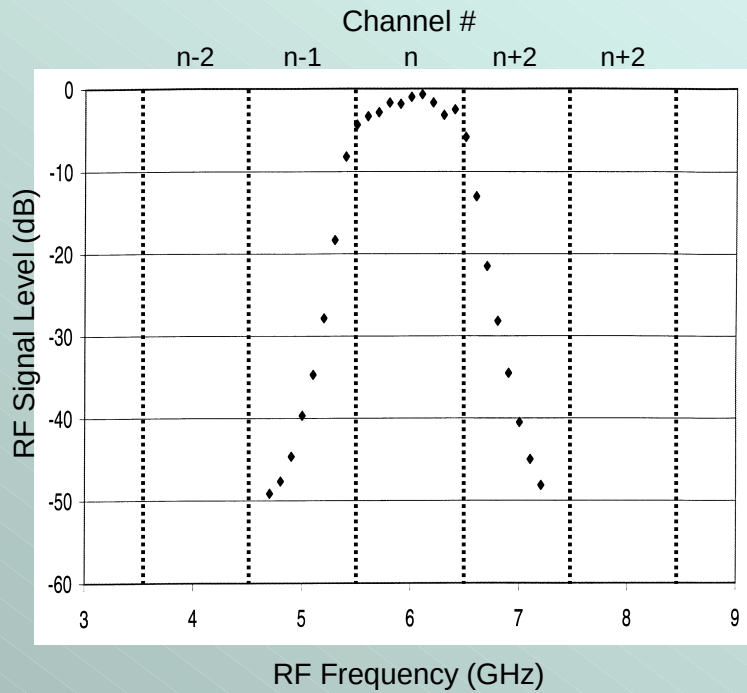


Measured SFDR into 3kHz noise BW	SFDR-BW product	Calculated SFDR-BW product
82dB	105.2dB $Hz^{2/3}$	108.0dB $Hz^{2/3}$

Single-Channel Frequency Response

Signal spot width is 3x local oscillator spot width

Intermediate frequency, IF = 6 GHz



Photonic Time Domain Processing

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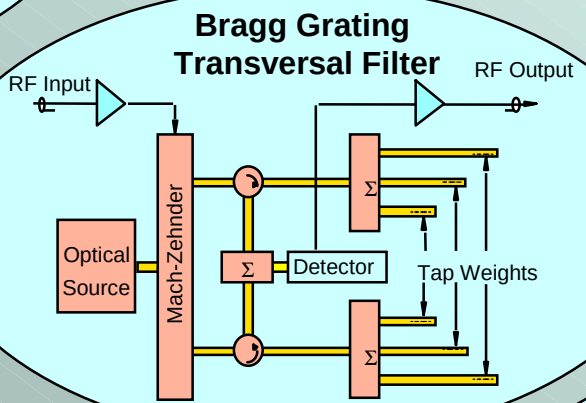
Mission Need

- Wideband Equalization
- Filtering
- Nulling, multipath cancellation

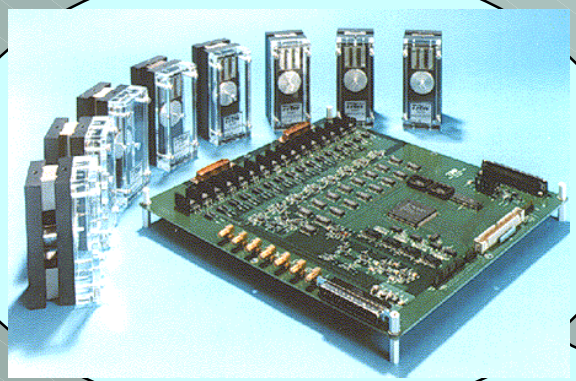
Photonic Subsystem Block Diagram



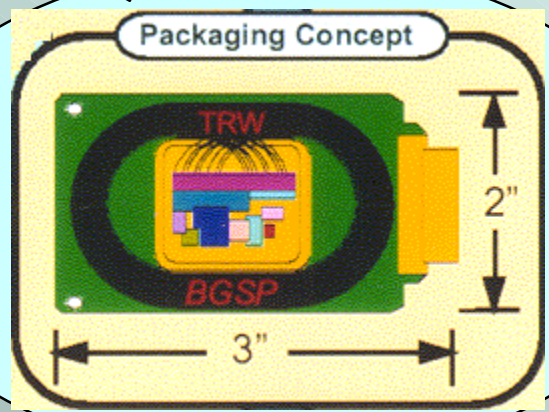
Key Enabling Technology

Optical True Time Delay

Proof of Concept Demonstration



Modular Concept



Four Tap Processor Filtering

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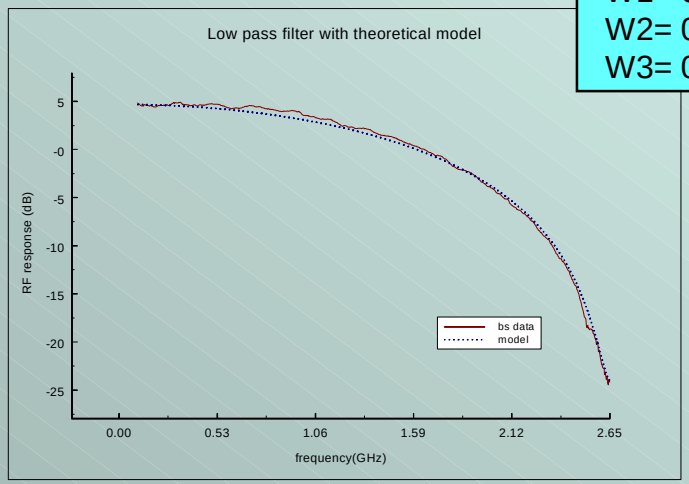
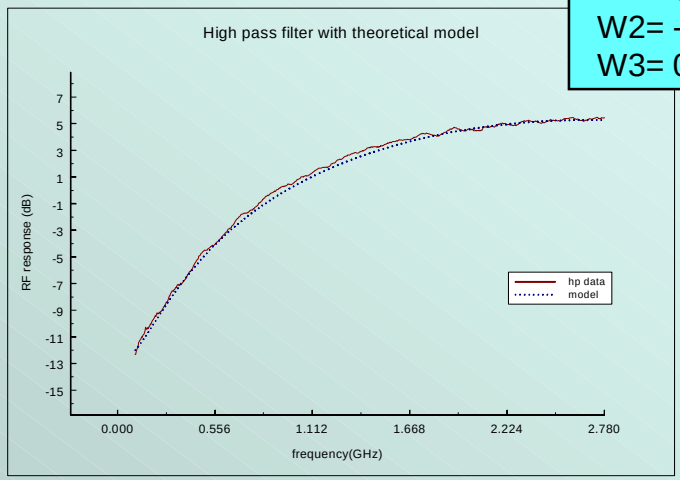
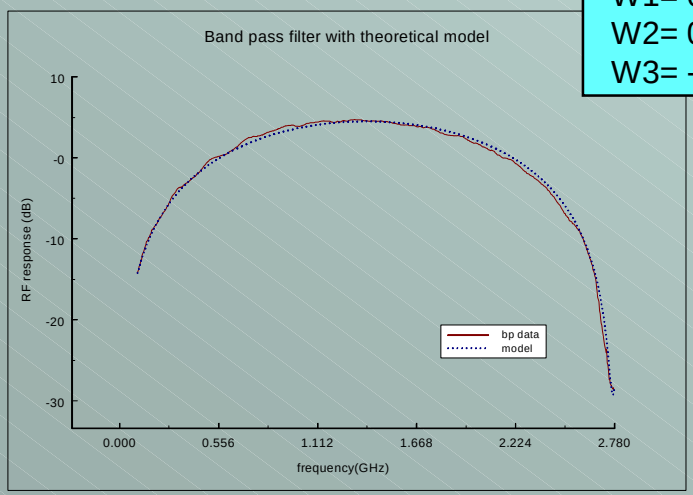
W1= 0.5
W2= 0.5
W3= 0.0



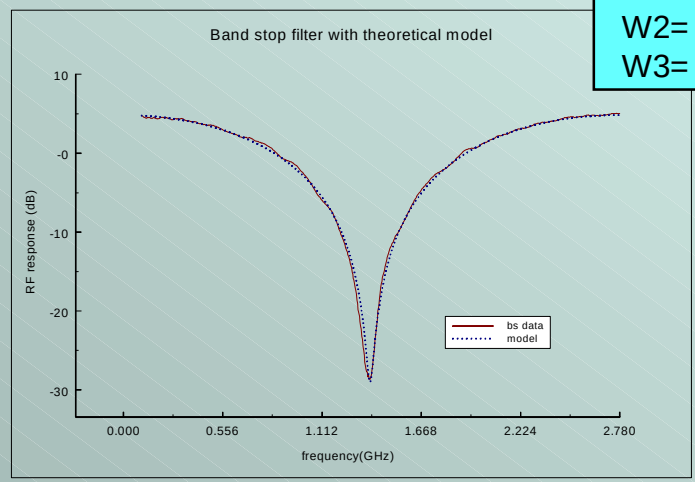
W1= 0.5
W2= -0.5
W3= 0.0



W1= 0.5
W2= 0.0
W3= -0.5



W1= 0.5
W2= 0.0
W3= 0.5



Photonic Image Reconstruction

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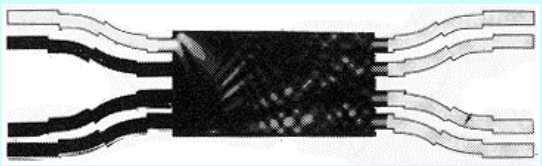
Mission Need

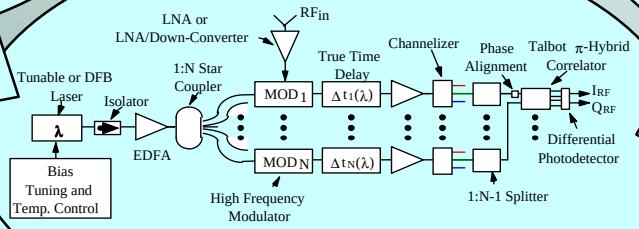
Key Enabling Technology

4x4 MMI Coupler



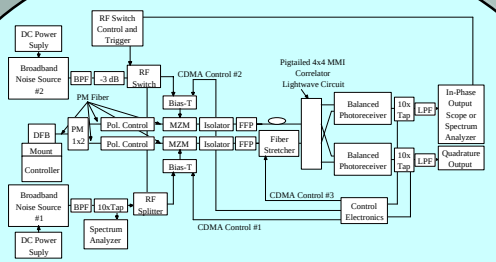
(Talbot Splitter)

Photonic Subsystem Block Diagram



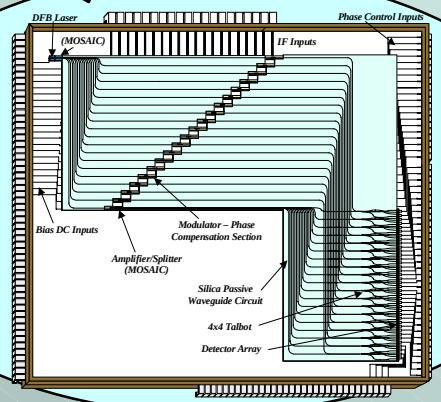
DARPA STO 1997
"PIPMMW" Study

Proof-of-Concept Demonstration



ONR DUS&T 1999
"OCSAR" Program

Modular Concept



Optical Correlation Offers Significant Size, Weight, Power Advantages

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Imaging Sensor Total Weight Estimates

Block	Electronic (kg)	Photonic/Electronic (kg)	Photonic (kg)
Antenna	31.8	31.8	31.8
Receiver	2.1	2.1	2.1[(1)]
Local Oscillator	7.8	7.8	0.0
Elec.Processor	119.2	0.0	0.0
Phot. Processor	0.0	22.3	22.3
Subtotal	**160.9**	**64.0**	**56.2**
Structure (50%)	80.5	32.0	28.1
Total	**241.4**	**96.0**	**84.3**

Note: (1) Mixers are not required but amplifiers are.

Imaging Sensor Total Power Estimates

Block	Electronic (W)	Photonic/Electronic (W)	Photonic (W)
Antenna	1176.0	1176.0	1176.0
Local Oscillator	162.8	162.8	0.0
Elec.Processor	1725.4	0.0	0.0
Phot. Processor	0.0	78.0	78.0
Total	**3064**	**1416.8**	**1254**

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Summary

- Technology will continue to “broaden” the useful RF spectrum
- We have spectrum processing problems today that are really hard and will only get harder
- Photonics can be *a part* of the solution
  - as a preprocessor to reduce load on downstream electronics
  - in some cases as the processor itself